BEFORE THE ENVIRONMENT COURT
I MUA I TE KOOTI TAIAO O AOTEAROA

UNDER	the Resource Management Act 1991
IN THE MATTER	of appeals under Clause 14 of the First Schedule of the Act
BETWEEN	**TRANSPOWER NEW ZEALAND LIMITED** (ENV-2018-CHC-26)
	FONTERRA CO-OPERATIVE GROUP (ENV-2018-CHC-27)
	HORTICULTURE NEW ZEALAND (ENV-2018-CHC-28)

(Continued next page)

STATEMENT OF EVIDENCE OF DR ANTONIUS SNELDER ON BEHALF OF SOUTHLAND REGIONAL COUNCIL

WATER QUALITY

11 February 2022

Judicial Officer: Judge Borthwick

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WILKINS FARMING CO
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GORE DISTRICT COUNCIL, SOUTHLAND DISTRICT COUNCIL & INVERCARGILL DISTRICT COUNCIL
(ENV-2018-CHC-31)

DAIRYNZ LIMITED
(ENV-2018-CHC-32)

H W RICHARDSON GROUP
(ENV-2018-CHC-33)

BEEF + LAMB NEW ZEALAND
(ENV-2018-CHC-34 & 35)

DIRECTOR-GENERAL OF CONSERVATION
(ENV-2018-CHC-36)

SOUTHLAND FISH AND GAME COUNCIL
(ENV-2018-CHC-37)

MERIDIAN ENERGY LIMITED
(ENV-2018-CHC-38)

ALLIANCE GROUP LIMITED
(ENV-2018-CHC-39)

FEDERATED FARMERS OF NEW ZEALAND
(ENV-2018-CHC-40)

HERITAGE NEW ZEALAND POUHERE TAONGA
(ENV-2018-CHC-41)

STONEY CREEK STATION LIMITED
(ENV-2018-CHC-42)

THE TERRACES LIMITED
(ENV-2018-CHC-43)

CAMPBELL'S BLOCK LIMITED
(ENV-2018-CHC-44)

ROBERT GRANT
(ENV-2018-CHC-45)

SOUTHWOOD EXPORT LIMITED, KODANSHA TREEFARM NEW ZEALAND LIMITED, SOUTHLAND PLANTATION FOREST COMPANY OF NEW ZEALAND
(ENV-2018-CHC-46)

TE RUNANGA O NGAI TAHU, HOKONUI RUNAKA, WAIHOPAI RUNAKA, TE RUNANGA O AWARUA & TE RUNANGA O ORAKA APARIMA
(ENV-2018-CHC-47)

PETER CHARTRES
(ENV-2018-CHC-48)

RAYONIER NEW ZEALAND LIMITED
(ENV-2018-CHC-49)

ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NEW ZEALAND
(ENV-2018-CHC-50)

Appellants

AND **SOUTHLAND REGIONAL COUNCIL**

Respondent

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Summary of Evidence

1 In my evidence I have responded primarily to a request from the planners to define maps showing the catchments of degraded water bodies. I have prepared these maps for a series of seven attributes for which there is sufficient data and models to undertake a complete and comprehensive assessment of the degradation status of all river and estuary water bodies in the region. I have produced a 'combined map' for which a catchment is categorised as 'degraded' if it is degraded for any of the seven attributes.

2 The combined map indicates that the entirety of the catchments that include the productive land in Southland are degraded. This indicates that either the main-stems of the rivers draining these catchments and/or the estuaries that the rivers discharge to, are degraded in terms of one or more of the seven attributes.

Introduction, qualifications and experience

3 My full name is Dr Antonius Hugh Snelder. I am a director of LWP Ltd and consultant and researcher in the field of water and land resources management. I hold a bachelor of agricultural engineering degree from the University of Canterbury, a post graduate diploma in hydrology from the University of New South Wales (Australia) and a PhD in environmental management from Lincoln University. I have 35 years of experience in the field of water resource management, including 14 years as a water resources scientist at the National Institute of Water and Atmosphere (NIWA), and prior positions in regional councils and in consultancies as a water resources engineer. I have published more than 50 papers concerned with land and water resources and management thereof in peer reviewed scientific journals. Since 2016 I have undertaken more than 40 studies concerned with land and water resources for regional councils and central government.

4 In relation to the appeals on the proposed Southland Water and Land Plan (**pSWLP** or **Plan**), I previously provided evidence to the Court on the topic of the Physiographic Zones and attended expert caucusing for Topic A in relation to defining degradation (Water Quality JWS of October 2019) and identifying degraded waterbodies (Water Quality JWS of November 2019). I also attended expert caucusing for Topic B in relation to Science / Water Quality, and Farm Systems.

5 I have been asked by the Southland Regional Council (**Council**) to prepare evidence for these proceedings.

Code of conduct

6 I confirm that I have read the Code of Conduct for expert witnesses as contained in the Environment Court Practice Note 2014. I have complied with the Code of Conduct when preparing my written statement of evidence, and will do so when I give oral evidence.

7 The data, information, facts, and assumptions I have considered in forming my opinions are set out in my evidence. The reasons for the opinions expressed are also set out in my evidence.

8 Other than where I state I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope

9 I participated in expert witness conferencing in relation to these proceedings, and signed the resulting Land Management / Farm Systems Joint Witness Statements dated 22 November 2021 and 6 December 2021, and the Science / Water Quality Joint Witness Statement dated 24-26 November 2021.

10 I have been asked by the Council to provide evidence in relation to the Joint Witness Statements I am a signatory to, and the following matter which was outstanding following the expert conferences:

(a) Mapping of degraded water bodies and their catchments.

Farm Systems expert conferencing and joint witness statements

11 I attended the Farm Systems expert conferencing. I am not an expert in farm systems and had no opinion on most of the matters discussed.

12 I have no opinion on points that were not agreed during the Farm Systems expert conferencing.

Science / Water Quality expert conferencing and joint witness statement

13 The Science / Water Quality conferencing (JWS dated 26 November 2021) responded to a series of questions relating to science and water quality including:

(a) the impact of applying ki uta ki tai to the identification of degraded water bodies;

(b) whether monitoring and modelling indicate that Southland's water bodies are improving towards hauora;

(c) whether a focus on hauora influences how to determine degradation;

(d) the linkages between the indicators of ecosystem and human health, and cultural indicators of health;

(e) whether in the context of farming, there needs to be any changes to the plan provisions to better achieve hauora;

(f) to what extent will there be water quality improvements achieved by farm environmental management plans;

(g) whether degraded is consistent with hauora;

(h) whether degraded water bodies and their catchments can be spatially identified (i.e., mapped); and

(i) whether there are any other outstanding matters or policy decisions that need to be resolved in order to define the maps.

14 We also discussed the effectiveness of cultivation setback rules. I standby the outcomes of this conference as set out in our JWS.

15 There remains an unanswered question regarding the classification of some of the larger rivers of the region. The main stems of some large rivers (for example the Waiau River; paragraph 30 in the November 2019 JWS) are classified as 'upland' despite flowing through the lowland areas of Southland. This is because the rules used for classification are based on decisions regarding the dominant source of water in these rivers. The rules in these cases imply that the water in these rivers is dominated by the flows from their upland catchments. However, in the lower reaches of these rivers, water quality can be disproportionately influenced by the contribution from the lowland areas. Therefore, there is

a view that the lower reaches of these rives should be classified as lowland. I address this below.

Matters not agreed at Science / Water Quality expert conferencing

16 The question of whether the lower reaches of the large upland rivers should be classified as lowland or upland remains unresolved. In my opinion there is not a scientific answer to this question because the subdivision of river systems into upland and lowland is an arbitrary point on a continuously varying gradient in river conditions, including the source of water and water quality and ecological character.

Designation of degraded water bodies

17 The Water Quality JWS of October 2019 provides the attributes and associated threshold values that define ‘degraded’ and ‘not-degraded’ water bodies. The experts involved in the Water Quality JWS of October 2019 considered two compulsory values, ecosystem health and human health (or human contact). Receiving environments included rivers, lakes and estuaries. The list of attributes and thresholds are summarised in Table 1 (Oct 2019 JWS).

18 It is my opinion that the threshold values used to define ‘degraded’ and ‘not-degraded’ water bodies cannot be determined scientifically or solely by experts. Decisions about what the threshold for a given attribute ‘should be’ implicitly involves trade-offs between different sets of values. These values are often recognised as belonging to one of four categories: social, cultural, economic and environmental. Science can describe the outcomes, for example, for ecosystem health and human health at different threshold values of a given indicator. I consider that economists and social and cultural scientists and/or experts can also describe the outcomes of different threshold values in terms of attributes that are used in these disciplines. However, the “right” threshold value implies a judgement about “how things should be” for all values. This judgement depends on the relative importance or rank given to the values and is therefore not a question a scientist can answer.

19 I was comfortable with the threshold values provided by the October 2019 JWS because we generally adopted the “national bottom-line” (**NBL**) or “minimum acceptable state” to define a ‘degraded’ condition. By basing the thresholds on the NBL, decisions about “how things

should be" are effectively based on the (then current) NPS-FM.[1] The October 2019 JWS contains some deviations to the adoption of the NBL that I discuss below.

20 In defining the threshold values that define 'degraded' and 'not-degraded' water bodies, the experts involved in the Water Quality JWS of October 2019 utilised a simple classification of Southland's rivers into 'Upland' and 'Lowland' classes. The rationale for this is that even under natural conditions, water quality indicators will vary longitudinally within catchments. Under natural conditions lower concentrations of contaminants (i.e., higher water quality) will occur in streams and rivers dominated by upland areas. Under natural conditions concentrations will increase in streams and rivers as the proportion of lowland area contributing to those waterbodies increases. It is reasonable therefore to expect water quality to be higher in streams and rivers draining upland areas (i.e., classified as Upland) compared to those draining lowland areas (i.e., classified as Lowland).

21 There are thresholds defined in Table 1 (Oct 2019 JWS) that are more stringent than NBLs defined by the NPS-FM 2017. The experts involved in the October 2019 JWS generally set these higher thresholds based on the observation that even under natural conditions, water quality can be expected to be higher in streams and rivers classified as Upland. The rationale for deviating from thresholds defined purely by the NPS-FM 2017 is that the NPS-FM is a national level regulation that provides only coarse direction regarding NBLs.

22 With respect to the toxicity attributes for nitrate and ammoniacal nitrogen, some experts considered that thresholds should be more stringent than the NBL. The experts agreed to dissolved inorganic nitrogen (**DIN**) thresholds that are considerably lower than the NBL for nitrate-nitrogen (note the DIN is predominantly nitrate-nitrogen). I am comfortable with the DIN thresholds defined in the Water Quality JWS of October 2019 because these are generally consistent with levels that are required to manage periphyton at the NBL threshold. The Water Quality JWS of October 2019 has two options for the ammoniacal nitrogen threshold; the NBL and the bottom of Band A (a more stringent

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1 Being the National Policy Statement for Freshwater Management 2014 (amended 2017) (**NPS-FM 2017**).

threshold than the NBL). As I have said above, I do not consider that the choice between these two thresholds is a scientific decision and this is the reason for the footnote in the JWS that indicates there was a difference of views between the experts.

Maps of catchments of degraded water bodies

23 During expert caucusing for Topic B (Science / Water Quality JWS November 2021), it was agreed that mapping of all areas where water quality is degraded is required. Because land draining to a degraded water body potentially contributes to the degradation, mapping needs to show all catchment areas in Southland that are upstream of degraded water bodies. I will refer therefore to maps of the catchments of degraded water bodies.

24 During expert caucusing for Topic B, the planners agreed that a single map of the catchments of water bodies degraded in terms of any one or more of nitrogen, phosphorus, sediment or microbial contaminants or cultural health indicators would be helpful. Furthermore, while a single map was requested, it was acknowledged that this could be built from series of layers representing different indicators of degradation and that it would be helpful to provide maps of the individual layers. I have undertaken analyses to construct these maps and my process for doing so it set out in the following section.

Degradation status of water bodies

25 Monitoring data is the most fundamental information that allows us to determine whether water bodies are degraded (based on the attribute thresholds discussed above). Monitoring of several water quality indicators is routinely undertaken in rivers, lakes and estuaries across the Southland region. The locations of river monitoring sites are shown in Figure 1 of the Water Quality JWS of November 2019. The lakes that are regularly monitored in the Region are described in Figure 17 of the Water Quality JWS of November 2019. The estuaries that are regularly monitored in the Region are described in Table 31 of the Water Quality JWS of November 2019. The regularly monitored rivers, lakes and estuaries are restricted to catchments that include productive land in Southland. There are no monitoring sites in Fiordland and on Stewart Island other than the Freshwater Estuary on Stewart Island. Freshwater

Estuary is an unimpacted estuary that is monitored as a 'control' or unmodified estuary for comparison.

26 There exists a great deal of documentation describing the data collected across Environment Southland's monitoring network and the analysis of observations to describe current state and trends with respect to those observations (e.g., Hodson et al. 2017; De Silva and Hodson 2020; Hodson and De Silva 2021). Measurements are made at monitored sites of several indicators including:

a. Algal biomass indicating eutrophication (rivers, lakes and estuaries)

b. Nutrients that stimulate algal growth (nitrogen and phosphorus) indicating potential eutrophication (rivers, lakes and estuaries)

c. Water clarity indicating sediment and other types of contamination (rivers and lakes)

d. Concentrations of the microbe *Escherichia coli* (*E. coli*) indicating human health risk (rivers)

e. Macro-invertebrate community indicating the health of the ecosystem (rivers and estuaries)

27 In general, an attribute is defined by a statistic, such as the median, which is calculated from the observations of an indicator at a monitoring site. The statistic (i.e., the attribute state) is considered to describe a relevant characteristic state at the monitored site.

28 It is general practice to calculate the statistics (i.e., the attribute states) from timeseries of the measured indicators for consistent time periods across all sites. In general, a timeseries of five years of duration is used to calculate the statistics. This is because the statistical precision of the statistic, and therefore the assessment of the attribute state, is determined by the number of observations that are used in its calculation. For a given level of variability, the precision of the attribute state assessment increases with the number of observations.

29 High precision is important when assessing the degradation status of sites. This is because when sites are close to a threshold the confidence that the assessment is 'correct' (i.e., that the site has been correctly designated as 'degraded' or 'not-degraded') increases with the precision of the calculated statistic (and therefore with the number of observations). A period of five years is used because this represents a reasonable trade-off between statistical precision and specificity with

respect to the time that the assessment applies to. In this analysis the five-year period was 2013 to 2017. This period was used because it is consistent with recent studies carried out in support of the Southland Regional Forum process (Neverman et al. 2020; Snelder 2021; Snelder and Fraser 2021).

30 The observed values of the indicators at the monitoring sites represent a (small) sample of the state of all the rivers, lakes and estuaries of Southland. To make a map of the catchments of degraded water bodies of Southland that is comprehensive (i.e., covers the entire region and exhaustively assesses all water bodies), it is necessary to infer the attribute state for all non-sampled rivers, lake and estuaries from the monitoring data. The first step in mapping the catchments of degraded water bodies is to use statistical models to predict the attribute states for all locations.

31 Statistical modelling is commonly used to predict the attribute state for non-sampled locations on rivers. The model is based on a digital representation of the river network where each ‘segment’ of the river network (section of stream or river between major confluences) is represented. More details of the digital river network and the modelling process are provided by Snelder (2021) and Whitehead (2018).

32 Statistical models are ‘trained’ using the monitoring data and are then used to predict the attribute state for every segment of the river network based on predictor data that describe the environmental characteristics in the upstream catchment, including the climate, topography, land cover and information describing the intensity of pastoral land use (i.e., animal stocking rates). Because there are databases that detail these environmental characteristics for all river segments in the region, statistical models can be used to predict current indicator values for all unmonitored segments. However, reliable predictions can only made for segments that have similar environmental characteristics to the monitoring sites. For this reason, reliable model predictions for rivers were restricted to the area that broadly encompasses the river monitoring sites, which includes: Aparima & Pourakino Catchments, Bluff Harbour Catchment, the Catlins Catchments, the Mataura Catchment, the Orepuki Catchments, the Ōreti & Invercargill Catchments, Te Waewae Bay Coastal Catchments, Tokanui Coastal Catchments, the Waiau Catchment, the Waikawa Catchment, the

Waimatuku & Taunamau Catchments and the Waituna Catchments. The streams and rivers in this area of the Southland Region are represented by approximately 43,000 individual segments.

33 The predictions made by statistical models incorporate a measure of the model's uncertainty. Model uncertainty arises because it is based on a small sample of the region's water bodies and the modelled relationships between the indicators and the environmental characteristics are an imperfect representation of the causes the state of the indicators. The uncertainty means that some predictions underestimate the true attribute state at a location, and some over-estimate its value. The level of uncertainty of the model is quantified as part of the modelling process and this result is used to inform about the reliability of the model. Models with very high levels of uncertainty are insufficiently reliable to be used.

34 In general terms, reliable models were able to be developed for Southland's rivers for a subset of the attributes that are listed in Table 1 of the Oct 2019 JWS. These included:

a. The median value of the nutrient dissolved inorganic nitrogen (**DIN**)

b. The median value of the nutrient dissolved reactive phosphorus (**DRP**)

c. The median value of visual water clarity (measured by black disc)

d. The four statistics describing the distribution of E. coli observations (median, 95th percentile (**Q95**), proportion of exceedances over 260 and 540 *E. coli* 100ml^{-1} (**G260**, **G540**).

e. The median value of the indicator of the stream invertebrate community health (i.e., ecological health) known as the macro-invertebrate community index (**MCI**).

35 Reliable models could also be developed to describe the annual loads of total nitrogen (**TN**) and total phosphorus (**TP**) discharged from rivers into estuaries. The details of the calculation of the annual TN and TP loads and the statistical modelling of these loads are fully described in (Snelder 2021).

36 Reliable models could not be developed for the lakes in the Southland region because there are insufficient monitored sites.

37 The models described above were developed using data obtained for sites in the Southland region only. Models of the same attributes have

frequently been developed that cover all of New Zealand (e.g., Whitehead 2018). The predictions made by the national models cover all Southland's rivers but tend to be less reliable than a 'region-specific' model because they are less focussed on the specific region of interest.

38 The second step in mapping the catchments of degraded rivers was to compare the predicted attribute values to the relevant thresholds at all locations. For rivers, this process simply compared the predicted values with those specified in the Oct 2019 JWS. Where necessary, the river locations were classified as Upland or Lowland and predicted attribute value was compared to the appropriate threshold. The thresholds used for the river attributes were obtained from the Oct 2019 JWS and are set out in Table 1 below. Where the comparison of the predicted attribute value and threshold indicated degradation, the segment was designated as 'degraded'.

Table 1. Thresholds for the river attributes used to assign river network segments as 'degraded' or 'not-degraded'. These thresholds were based on Table 1 of Oct 2019 JWS but see footnotes for some further details.

Attribute (statistic)	River Class	Threshold for degraded
DIN (median)	Upland	>0.5 mg/l
	Lowland	>1.0 mg/l
DRP (median)	Upland	>0.018 mg/l
	Lowland	>0.01 mg/l
Suspended sediment (Median Water Clarity[2])	Various[3]	As specified by NPS-FM NBL.
E. coli (median)[4]	All rivers	>130 E. coli /100 ml
E. coli (Q95)		>1200 E. coli /100 ml
E. coli (G260)		>0.34
E. coli (G540)		>0.2
MCI (median)	Upland	<100
	Lowland	<90

39 The third step in mapping the catchments of degraded rivers was to identify the catchment areas upstream of the network segments that

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2 The 2019 JWS specified turbidity, which is an alternative measure of the optical properties of water to visual clarity. This was because at the time of the JWS the draft NPS-FM (2020) specified turbidity but this was later changed to visual clarity. Visual clarity was used in the analysis to be consistent with the NPS-FM.

3 The NPS-FM (2020) has a prescribed classification of New Zealand's rivers into four classes for the purpose of defining the NBL for the suspended sediment attribute (which is based on the visual clarity indicator). The NPS-FM suspended sediment attribute classes were used in this analysis to assign a threshold to each river segment.

4 Segments were assigned as degraded if any of the four E. coli thresholds were exceeded. The 2019 JWS only defined the threshold of >130 for the median but this analysis used all four statistics to be consistent with the NPS-FM (2020).

were designated as ‘degraded’. This process was carried out by extending the ‘degraded’ designation in the upstream direction using the digital river network. A diagrammatic explanation is shown in the evidence of Dr Craig Depree (Figure 3). An example of the outcome of this process applied to the MCI indicator is shown in Figure 1.

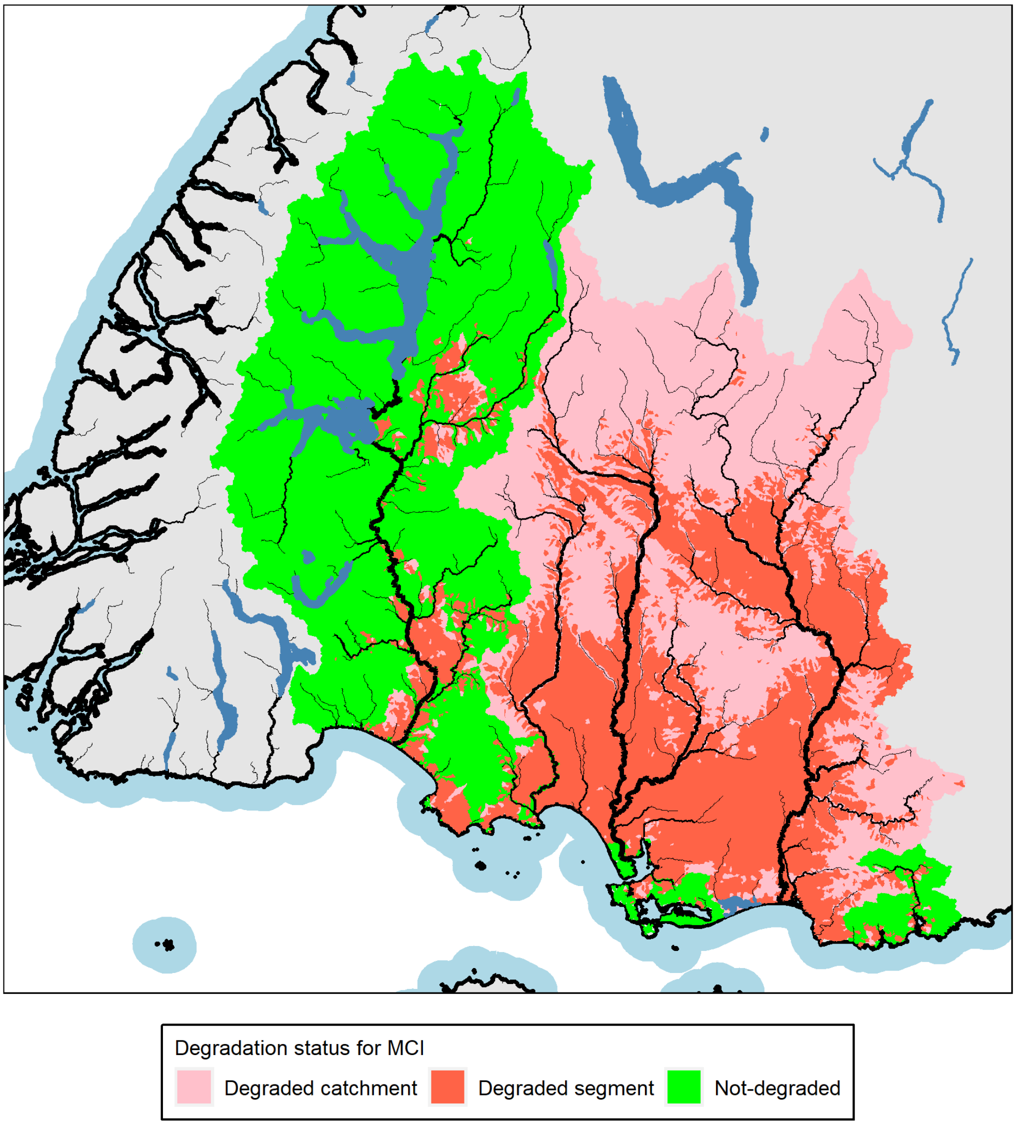

Figure 1. Map of the degradation status for rivers based on the MCI attribute. The red areas indicate the segments that are designated ‘degraded’. The pink areas area indicates catchments upstream of ‘degraded’ segments. The green areas indicate areas that are designated ‘not-degraded’.

40 Mapping of the catchments of degraded estuaries followed a different process to that set out above for rivers. Comprehensive assessment of the state of estuaries in Southland (i.e., assessment of all estuaries) can only be robustly performed based on modelling of the loads of total nitrogen (TN) and total phosphorus (TP) delivered to the estuaries from the upstream catchment. Statistical modelling is used to make predictions of the current TN and TP for unmonitored network segments in a similar manner to the river attribute state predictions. The training data are TN and TP loads calculated from observations at the monitoring sites. Reliable load estimates can therefore only be made for segments that have similar environmental characteristics to the monitoring sites. For this reason, reliable predictions of current TN and TP loads were restricted to the area that broadly encompasses the river monitoring sites, which comprises the catchments that include productive land in Southland and excluded Fiordland and Stewart Island. These predictions were used to estimate the current TN and TP loads delivered to 11 estuaries downstream of productive land in Southland (**Figure 2**).

41 The acceptability of the estimated current TN and TP loads delivered to the 11 estuaries shown in **Figure 2** were assessed by comparing them with loads that will produce specified outcomes for attributes that represent 'trophic state'. The trophic state of a water body indicates the amount of biological productivity it sustains. The relevant trophic state attributes for estuaries are defined in the 2019 JWS as phytoplankton (i.e., algae suspended in the water column of an estuary) and macroalgae cover (i.e., the coverage by macroalgae attached to the bottom of intertidal areas of an estuary).

42 In this analysis, the estimated current loads of TN and TP were compared to a maximum allowable load (**MAL**). The MALs corresponded to attribute thresholds (i.e., they were the TN and TP loads that could be expected to produce attribute states for phytoplankton and macroalgae that are equal to the respective thresholds). The equivalence between TN and TP loads and the attribute states were derived for each of 11 Southland estuaries using modelling that is described by Plew (2020). Plew (2020) defined MALs for TN and TP for the 11 Southland estuaries corresponding to thresholds for phytoplankton biomass defined by the 90th percentile of chlorophyll-*a* concentrations (μg/l). In this analysis, MALs were obtained for each

estuary from Plew (2020) that correspond to the phytoplankton and macroalgae attribute thresholds for degraded state defined in the October 2019 JWS (Table 2).

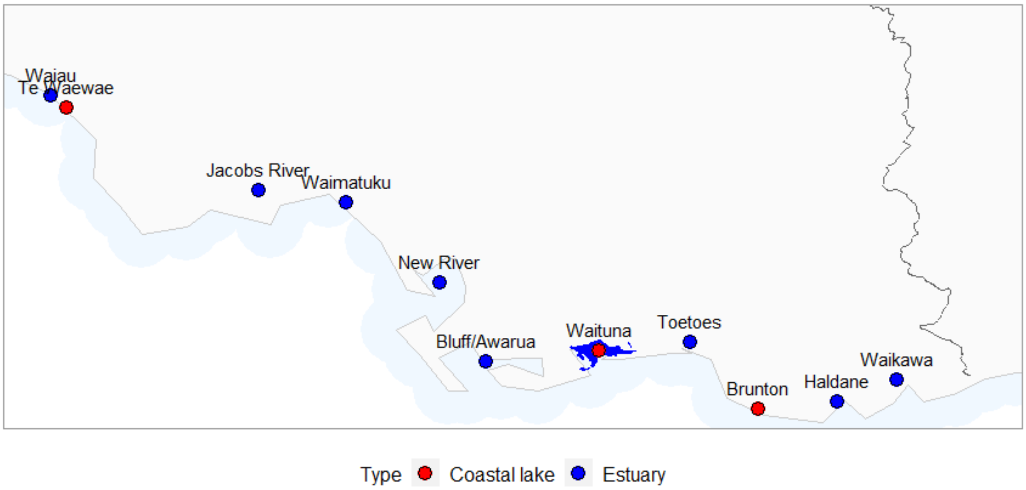

Figure 2. The 11 estuaries downstream of productive land in Southland that were included in the assessment of catchments of degraded estuaries. Note that Te Waewae lagoon, Waituna Lagoon and Lake Brunton are a special type of estuary that is referred to as a coastal lake. These three coastal lake estuaries were included in the assessment.

43 Plew (2020) also defined MALs for TN for the 11 Southland estuaries corresponding to thresholds for macroalgae expressed as the Ecological Quality Ratio (**EQR**). Plew (2020) assumed that susceptibility to macroalgal blooms is determined by TN concentrations (and not TP) because estuaries that support macroalgae are well flushed and sea water has ample phosphorus to support algal growth. In this analysis, MALs that correspond to the EQR thresholds for degraded state defined by the October 2019 JWS were obtained for each estuary from Plew (2020) (Table 2).

Table 2. Thresholds for the estuary attributes used to assign estuaries as 'degraded' or 'not-degraded'. These thresholds were based on Table 1 of Oct 2019 JWS but see footnotes for some further details.

Attribute	Estuary Type[5]	Threshold for degraded
Phytoplankton biomass	Euhaline	Chlorophyll-a >12 µg/l
	Meso/Polyhaline	Chlorophyll-a >16 µg/l
	Oligohaline/coastal lake	Chlorophyll-a >60 µg/l
Macroalgae biomass	NA	EQR > 0.4

[5] The thresholds for the phytoplankton attribute differ across estuaries of differing type as defined by the NPS-FM (2020).

44 The first step in mapping the catchments of degraded estuaries was to compare the predicted loads of TN and TP to the MALs defined by Plew (2020). Where the comparison of the predicted load exceeded the MAL, the estuary was designated as 'degraded'.

45 The second step followed the same process as for rivers to identify the catchment areas upstream of the degraded estuaries. This process was carried out by extending the 'degraded' designation for estuaries in the upstream direction using the digital river network. An example of the outcome of this process applied to TN is shown in **Figure 3**.

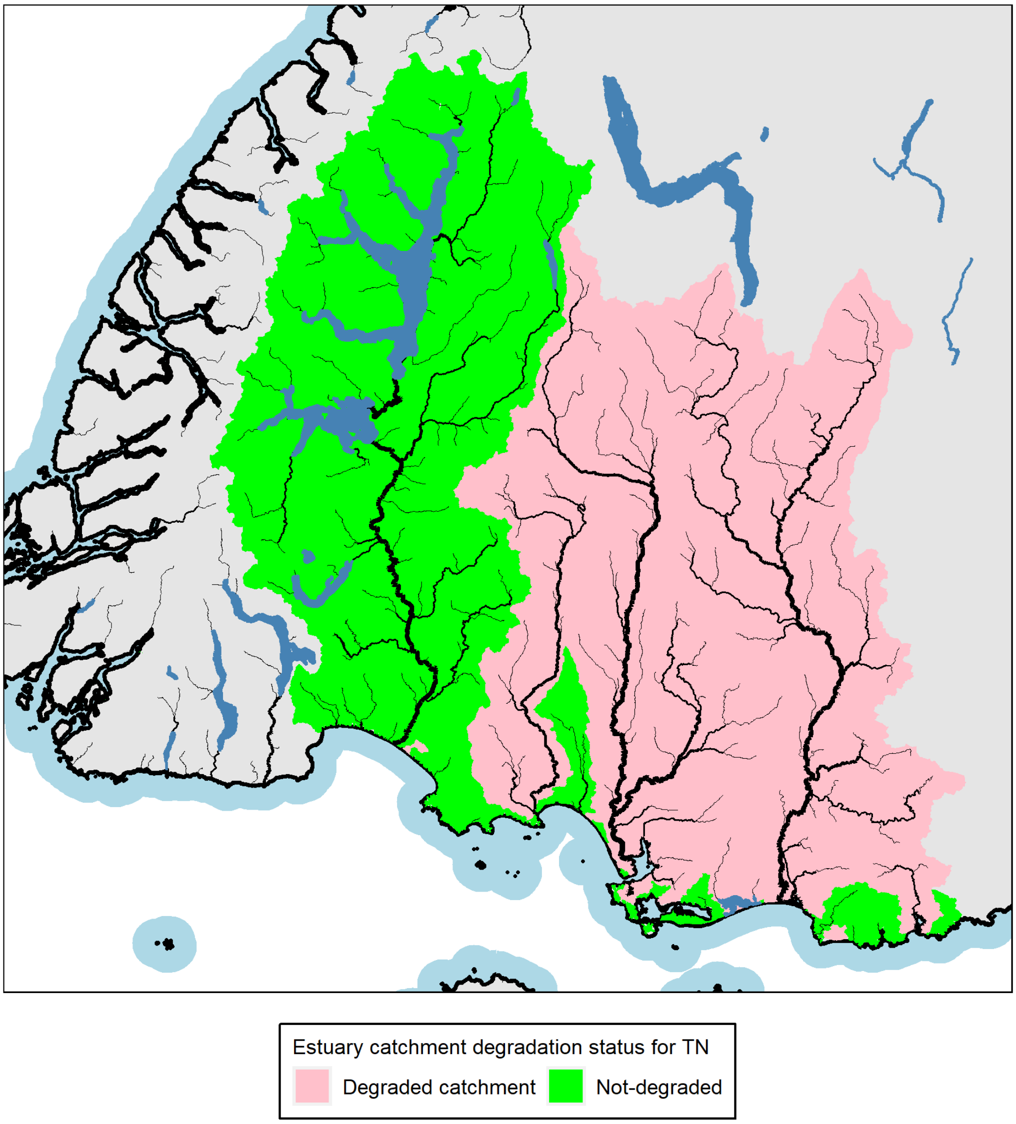

Figure 3. Map of the degradation status for estuaries based on the total nitrogen attribute (Table 2). The pink areas area indicates catchments upstream of 'degraded' estuaries. The green areas indicate areas that are designated 'not-degraded'.

46 The maps resulting from the process described above for each of the attributes shown in Tables 1 and 2 are appended to this evidence. **Figure 4** below is a map that combines all seven attributes shown in Tables 1 and 2 (the 'combined map'). This map (**Figure 4**) is what the planners considered would be helpful as part of their Topic B conference. In accordance with the planner's request, on the combined map, a catchment is categorised as 'degraded' if it is degraded for any of the seven attributes shown in Tables 1 and 2.

47 **Figure 4** indicates that the entirety of the catchments with appreciable productive land use in Southland are categorised as 'degraded'. Some catchments that are categorised as 'degraded' on the combined map (**Figure 4**), are categorised as 'degraded' for only one or two of the individual attributes. For example, much of the Waiau Catchment is only categorised as 'degraded' for the *E. coli* attribute. However, because the main stem of the Waiau river is 'degraded' for the *E. coli* attribute state, the entire catchment is categorised as 'degraded' on the combined map.

Figure 4. Map of the degradation status for rivers and estuaries based on all attributes shown in Tables 1 and 2. The pink areas area indicates catchments upstream of 'degraded' water bodies (i.e., estuaries and/or rivers). The green areas indicate areas that are designated 'not-degraded'.

Evidence of Dr Depree

48 In his evidence, Dr Depree has produced degraded catchment maps using the same process that I have used. Dr Depree has referred to these as 'maps of catchments in need of improvement', however he has used thresholds from the same source (the Oct 2019 JWS) as my analysis. I consider that the intent of the two sets of maps is therefore equivalent and my terminology 'catchments of degraded waterbodies'

has the same meaning as Dr Depree's term 'catchments in need of improvement'.

49 Dr Depree has proposed that the maps be produced from the least number of attributes as possible to avoid confusion. The approach to avoiding multiple maps that I have taken was to produce a map for those attributes for which reliable models could be constructed and then using all maps to make the combined map (**Figure 4**).

50 Dr Depree has used an alternative approach and constructed maps for two attributes for rivers (MCI and *E. coli*) that he suggests are representative and encompassing of two compulsory values, ecosystem health and human contact. I agree with Dr Depree that his approach has the merit of simplicity. I also agree that MCI might be regarded as holistic measure of ecosystem health. However, the water quality experts have defined 'degraded' and 'not-degraded' water bodies based on multiple attributes and have not declared that any one attribute has precedence or can be used as a proxy for the others. Furthermore, the NPS-FM has multiple attributes and does not declare that any one attribute has precedence or can be used as a proxy. In my opinion, in the absence of direction to the contrary, it is appropriate to define 'degraded' and 'not-degraded' water bodies based on all available attributes and to assume that a 'degraded' status for any one attribute means the water body should be classified degraded (i.e., the 'combined map', **Figure 4**).

51 There is a high degree of correspondence between the maps for individual river attributes that Dr Depree produced, and the maps presented here in my evidence. For example, the map of degradation status for catchments based on MCI shown in Figure 4 of Dr Depree's evidence is very similar to the map that I have produced (Figure 1, this evidence). Dr Depree's map of degradation status for catchments based on *E. coli* shown in Figure 7 of his evidence differs to some extent to the equivalent that I have produced (Figure 6, this evidence).

52 Differences between maps of the degradation status for rivers arise because the underlying model predictions used by Dr Depree and myself differ. Dr Depree has based his maps on predictions made using a national model whereas I have based my maps on region-specific predictions. As I have explained above, in my opinion, region-specific

models are preferable because they are focussed on the specific region of interest. In recent work supporting Environment Southland's Regional Forum process, the models that were used have been region-specific for this reason (Snelder 2021; Snelder and Fraser 2021). Despite the difference in the underlying models, the only catchment where differences between Dr Depree's assessment and mine are appreciable is the Waiau River catchment. The differences will have little to no impact because the parts of the Waiau River catchment that I have classified as 'degraded', but Dr Depree has classified as 'not-degraded', are largely in a natural state. It is my understanding therefore, that the degraded classification in these locations will have no impact because there are no land users.

53 Dr Depree has used an alternative approach and constructed maps for two attributes for estuaries. Dr Depree used the assessment of estuaries provided in the Water Quality JWS (Nov 2019). This assessment was based on irregular monitoring of eight estuaries of productive land in Southland. That assessment indicated that the Waituna Lagoon, Jacob River Estuary (Aparima catchment) and New River Estuary (Oreti Catchment) were degraded. Dr Depree's map of 'catchments in need of improvement' (i.e., what I refer to as 'catchments of degraded waterbodies') has identified the catchments of the Waituna Lagoon, Aparima River and Oreti River. In contrast, my analysis defined the following estuaries as degraded (either for TN, TP or both): Waikawa Harbour, Haldane Estuary, Lake Brunton, Toetoes Estuary, Waituna Lagoon, New River Estuary, and Te Waewae Lagoon. Therefore, my analysis has classified the catchments upstream of these estuaries as 'degraded'.

54 Differences between maps of the degradation status for estuaries between Dr Depree and this evidence is because of the differences in the approaches used. Dr Depree has used summaries of the attribute state of six estuaries presented in the Water Quality JWS (Nov 2019) to determine which estuaries are degraded. These state summaries are based on irregular and infrequent measurement of conditions in six of Southland's estuaries. For example, macroalgae measurements were first conducted for Southland estuaries in the 2000s for Bluff Harbour (2004), Haldane Estuary (2005), Waikawa Harbour (2004), Jacobs River Estuary, New River Estuary (2007), Fortrose (2003), Freshwater (2007)

and Waimatuku (2008). However, monitoring has not been undertaken every year for all the estuaries. Regular annual monitoring for New River Estuary, Jacobs River Estuary and Fortrose Estuary was undertaken from 2008 to 2013 but then experienced a hiatus until 2017 onwards. The focus on these three estuaries has been because they have high likelihood of eutrophication due to catchment pressure (i.e., they have appreciable productive land in their catchments). Because monitoring is irregular and infrequent (undertaken on one occasion in a sampling year), it provides a snapshot of conditions at the time of sampling. The 'potential trophic state' of an estuary (i.e., maximal levels of biomass such as macroalgae) only occur occasionally in association with favourable conditions (e.g., after a period with low river inflows and warm settled weather). The snapshots of conditions captured by Environment Southland's monitoring is therefore an incomplete picture of the estuaries 'potential trophic state'.

55 I have based my assessment on comparing derived criteria (MALs) with predicted nutrient loads (TN and TP) discharged to all 11 estuaries downstream of productive land in Southland. In my opinion, my method is a more appropriate approach for two reasons. First, my method is not based on a snapshot in time. Rather it provides a complete picture of an estuary's 'potential trophic state' by comparing the annual load of nutrients (TN and TP) with criteria. The criteria are based on modelling that was informed by Environment Southland's estuary monitoring data but that "fills in" the unsampled time that is not covered by the monitoring. Second, the use of modelling means that my assessment is comprehensive (i.e., it covers all 11 estuaries that are downstream of productive land in Southland).

Conclusion

56 In my evidence I have responded primarily to a request from the planners to define maps showing the catchments of degraded water bodies in the Southland Region. I have produced a 'combined map' (Figure 4) for which a catchment is categorised as 'degraded' if it is degraded for any of the seven attributes shown in Tables 1 and 2.

57 The combined map indicates that the entirety of the catchments that include the productive land in Southland are degraded. This indicates that either the main-stems of the rivers draining these catchments and/or

the estuaries that the rivers discharge to, are degraded in terms of one or more of the attributes shown in Tables 1 and 2.

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Antonius Hugh Snelder
11 February 2022

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Appendix 1. Mapping of catchments of degraded water bodies based on each attribute shown in Tables 1 and 2.

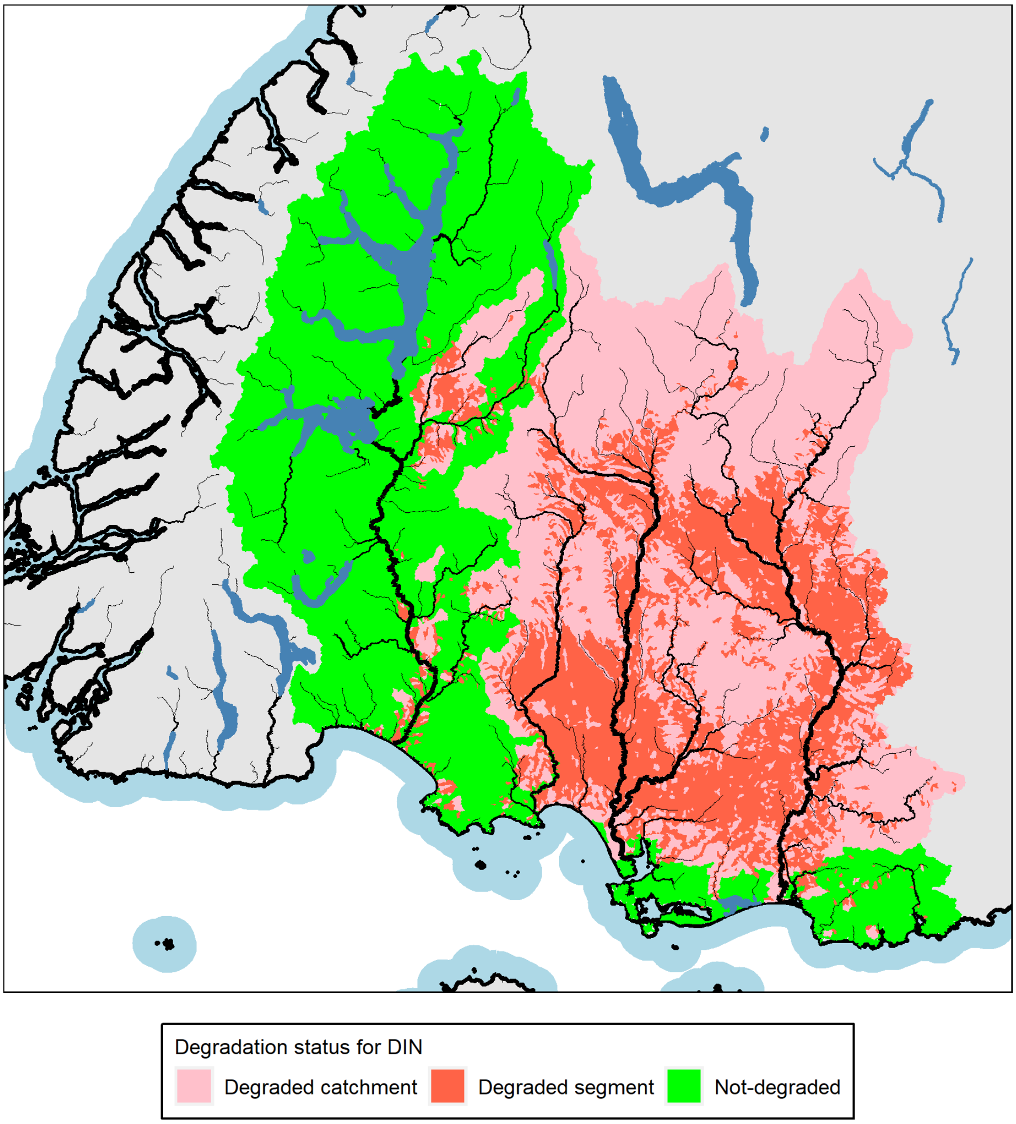

Figure 5. Map of the degradation status for rivers based on the DIN attribute. The red areas indicate the segments that are designated 'degraded'. The pink areas area indicates catchments upstream of 'degraded' segments. The green areas indicate areas that are designated 'not-degraded'.

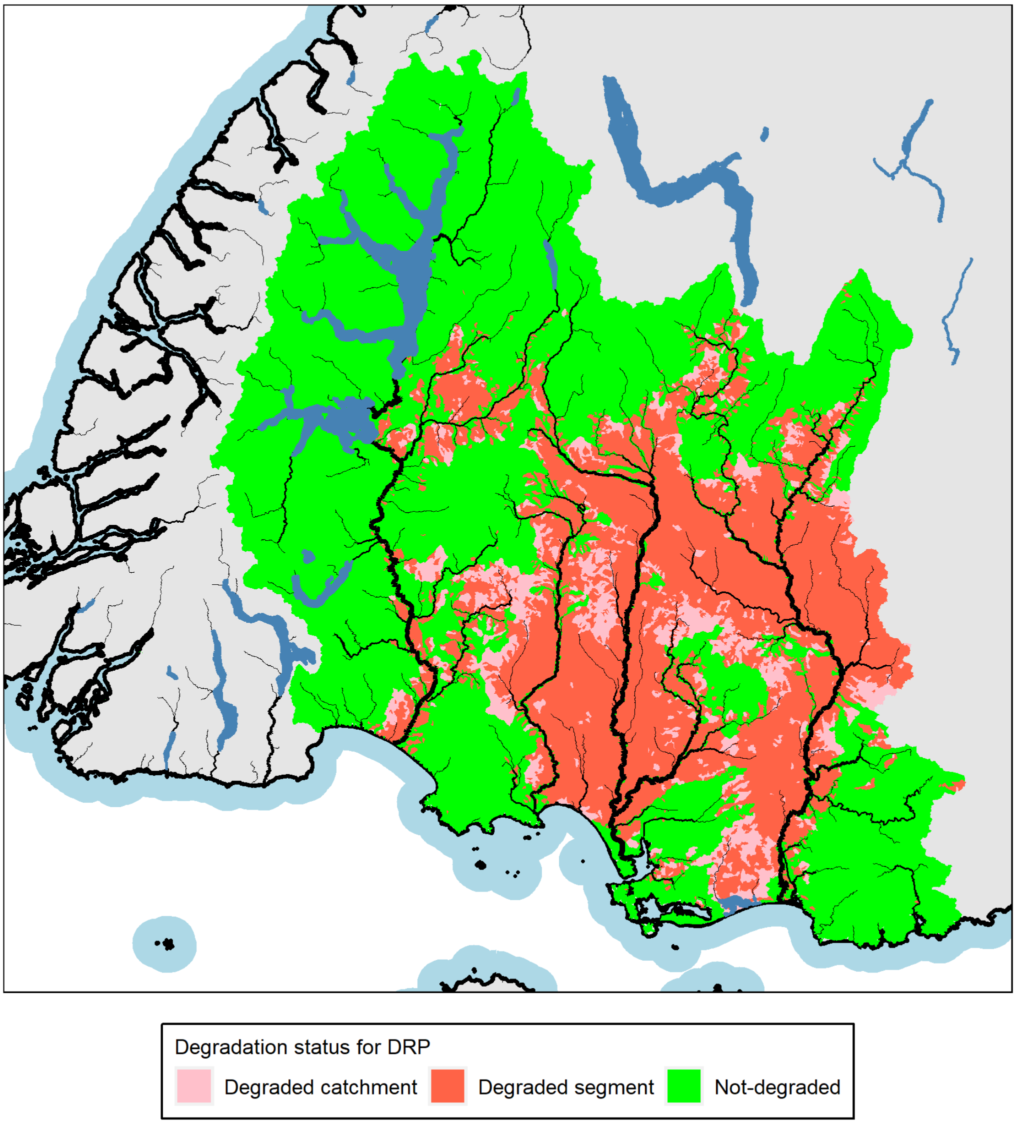

Figure 6. Map of the degradation status for rivers based on the DRP attribute. The red areas indicate the segments that are designated 'degraded'. The pink areas area indicates catchments upstream of 'degraded' segments. The green areas indicate areas that are designated 'not-degraded'.

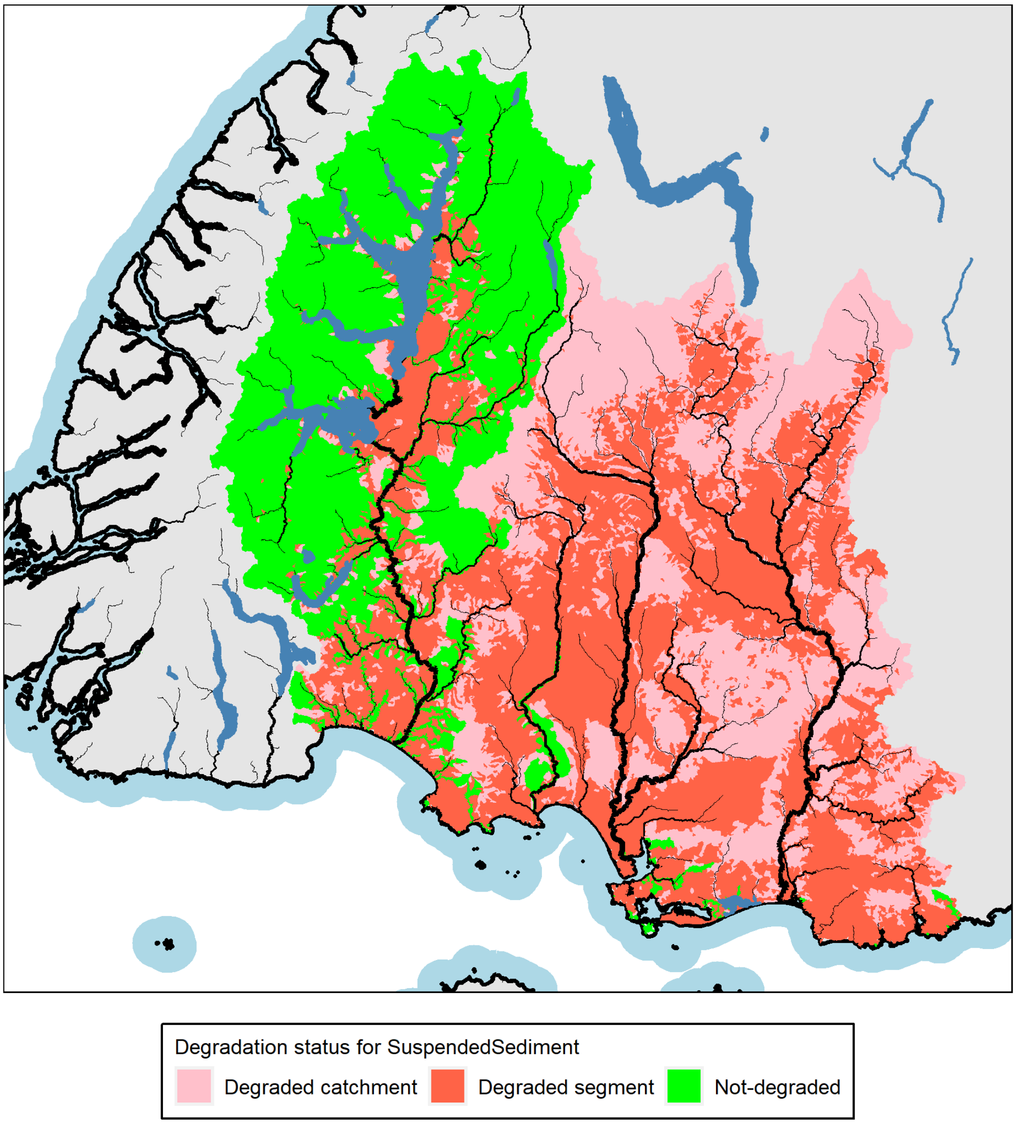

Figure 7. Map of the degradation status for rivers based on the suspended sediment attribute. The red areas indicate the segments that are designated 'degraded'. The pink areas area indicates catchments upstream of 'degraded' segments. The green areas indicate areas that are designated 'not-degraded'.

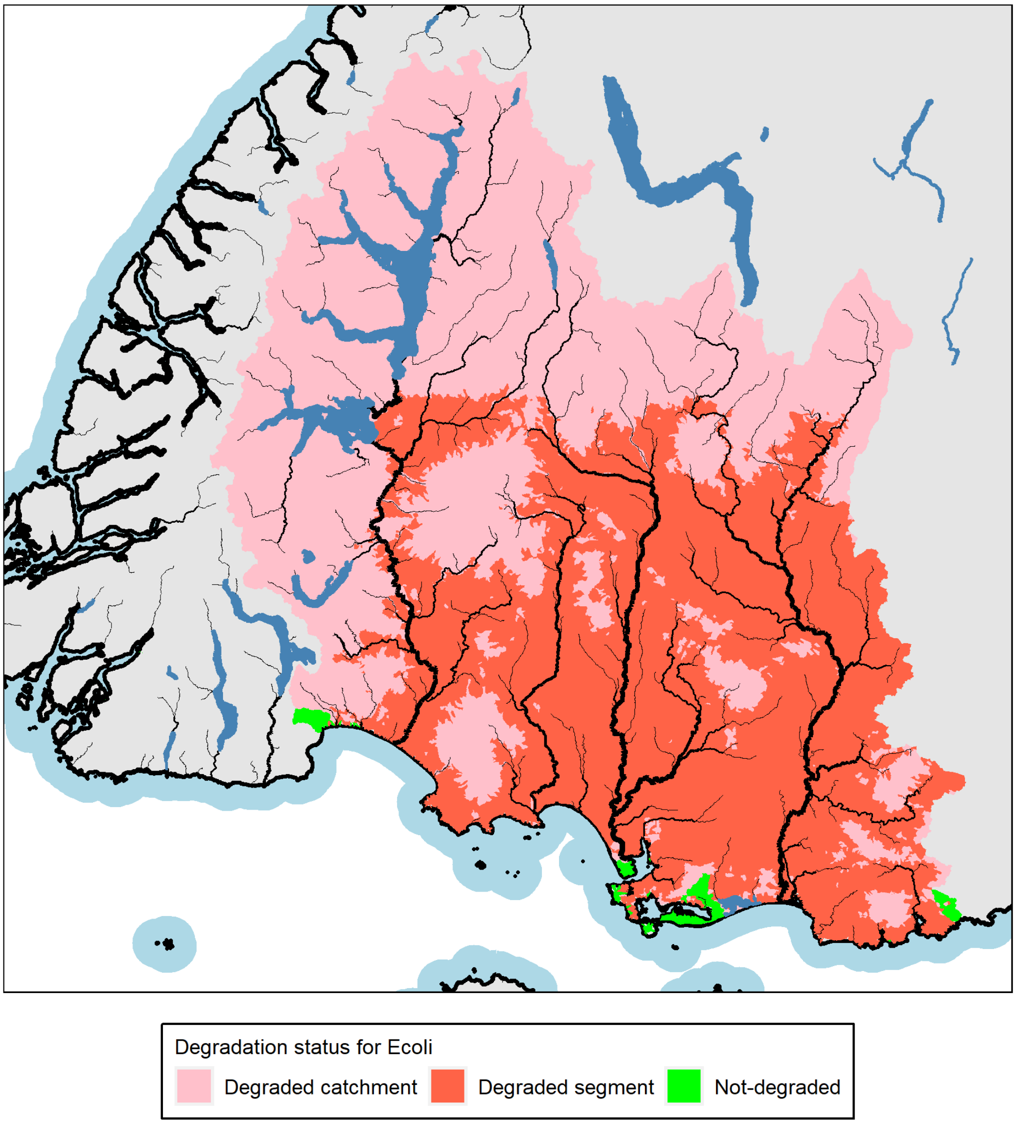

Figure 8. Map of the degradation status for rivers based on the E. coli attribute. The red areas indicate the segments that are designated 'degraded'. The pink areas area indicates catchments upstream of 'degraded' segments. The green areas indicate areas that are designated 'not-degraded'.

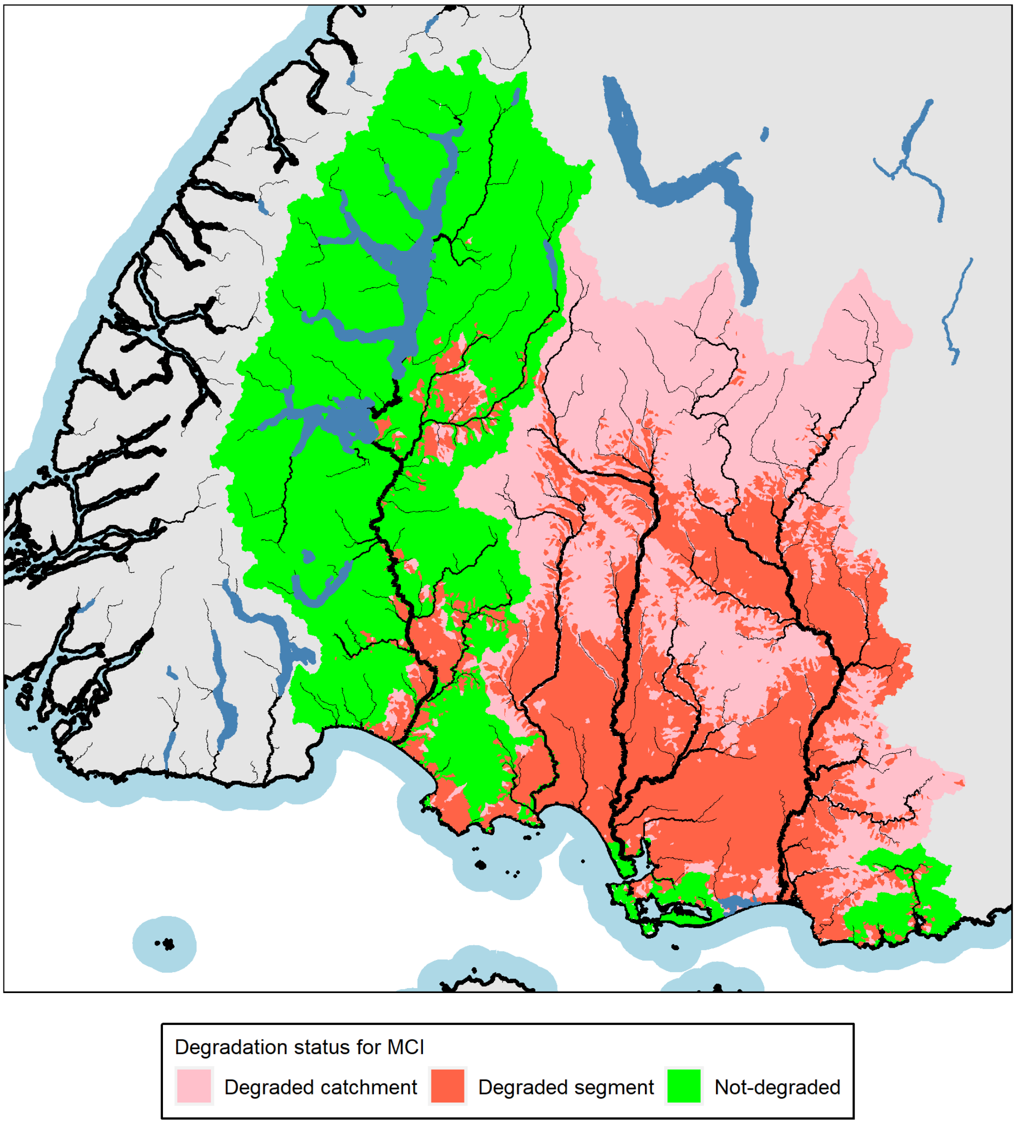

Figure 9. Map of the degradation status for rivers based on the MCI attribute. The red areas indicate the segments that are designated 'degraded'. The pink areas area indicates catchments upstream of 'degraded' segments. The green areas indicate areas that are designated 'not-degraded'.

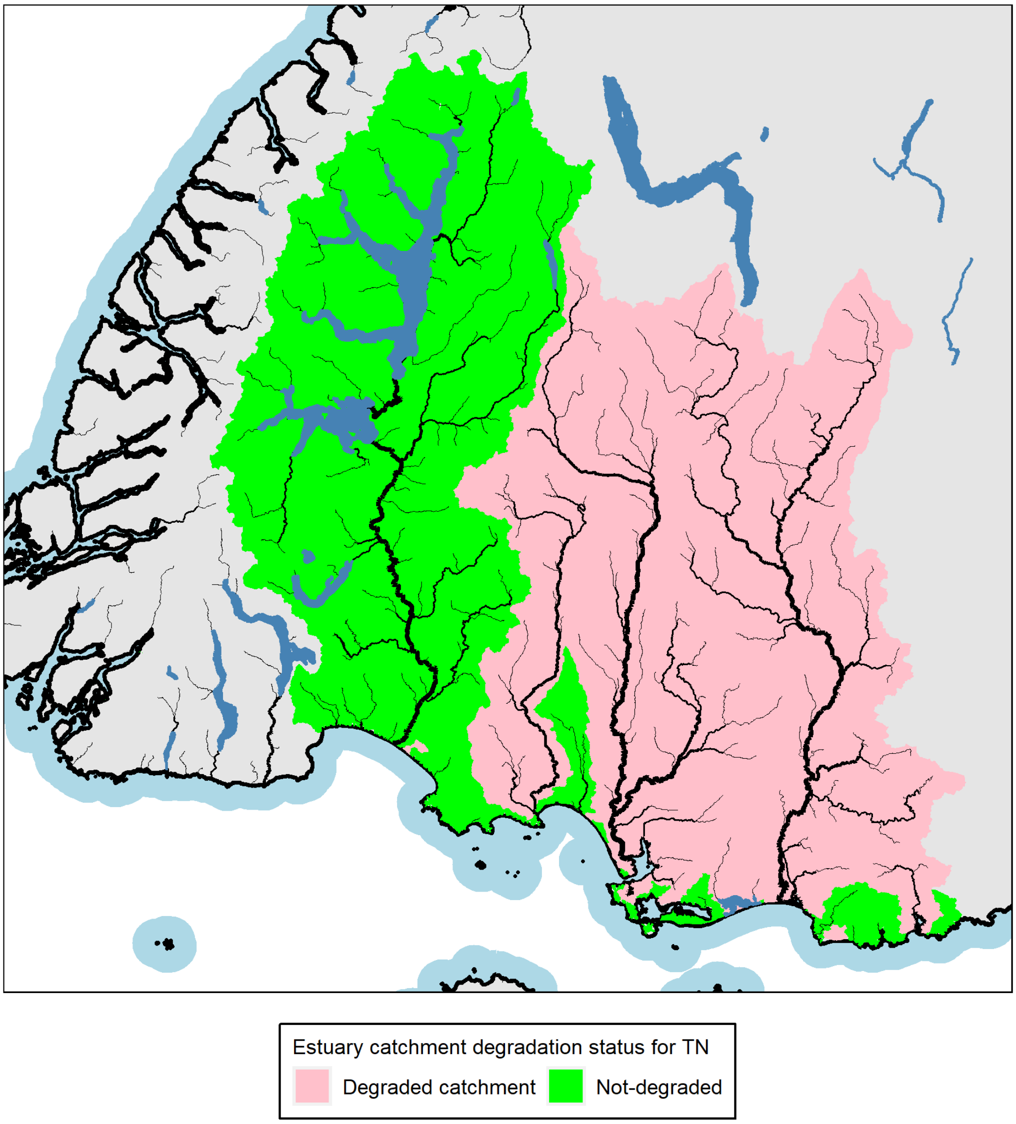

Figure 10. Map of the degradation status for rivers based on the estuary TN attribute. The red areas indicate the segments that are designated 'degraded'. The pink areas area indicates catchments upstream of 'degraded' segments. The green areas indicate areas that are designated 'not-degraded'.

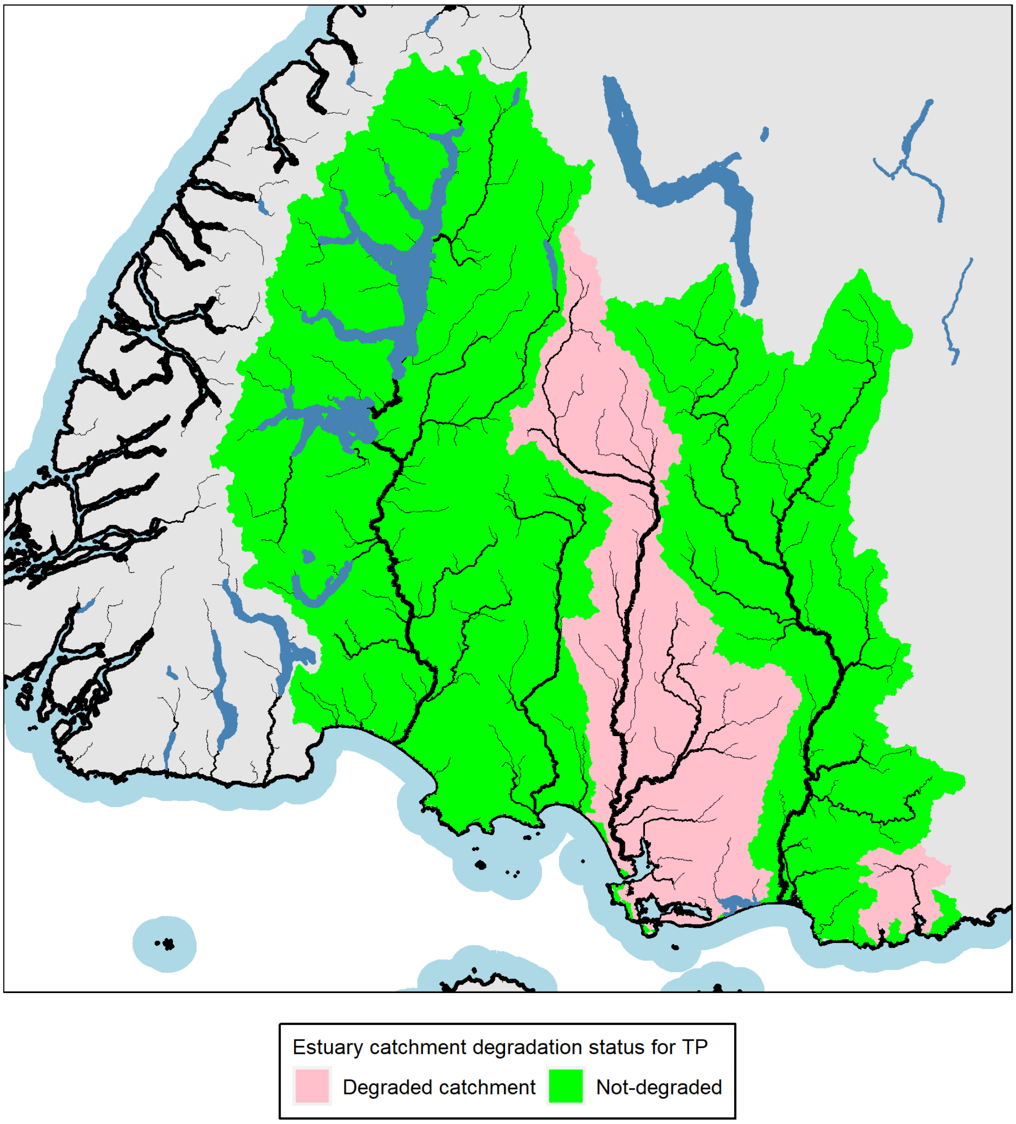

Figure 11. Map of the degradation status for rivers based on the estuary TN attribute. The red areas indicate the segments that are designated 'degraded'. The pink areas area indicates catchments upstream of 'degraded' segments. The green areas indicate areas that are designated 'not-degraded'.